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## 1. INTRODUCTION

A severe microburst occurred on 2 July 1994 at Charlotte, NC, and was associated with the crash of USAir Flight 1016 (FL-1016) (Salottolo 1994; Phillips 1994). The inbound DC-9 unexpectedly encountered a rapidly intensifying rainshaft just seconds before it was to touchdown on runway 18R. The aircraft crashed after encountering strong windshear, killing 37 of the 57 souls on board. The pilots did not recognize the windshear condition in time to prevent the accident and received no warning from the aircraft's Honeywell in-situ windshear detection system or from ground-based systems (Charlotte maintains both an ASR-9 weather radar and a Phase-2 LLWAS). Also two other aircraft landed ahead of FL-1016 without incident and reported smooth approaches to 18R. Section-2 of this paper reports briefly on the reconstruction of the event based on numerical results generated by the Terminal Area Simulation System (TASS) as presented at the National Transportation Safety Board (NTSB) public hearing (Proctor 1994). Section-3 discusses the simulation of this event with a look-ahead windshear radar.

## 2. MODEL RECONSTRUCTION

The event is reconstructed from data generated by TASS, a three-dimensional, time-dependent, cloud model which includes parameterizations for both liquid- and ice-phase microphysics. As a key element in NASA's recent windshear program, the TASS model has been applied to a diversity of microburst cases (Proctor 1988a,b, 1992, 1993; Proctor and Bowles 1992) and has supplied the FAA with a variety of model-generated data sets for use in industry certification of look-ahead windshear systems (Switzer et al 1993). The model data sets, once validated, have four valuable applications: 1) aid in understanding the "science" of the event, 2) aid in reconstructing the event and filling in "holes" or providing variables unavailable from observations, 3) provide a means for testing and evaluating sensor capabilities, and 4) can be used in flight simulator studies to evaluate "what if" scenarios.

The numerical simulation assumes a  $15.6 \times 15.6 \times 11$  km domain with a horizontal grid size of 125 m and a vertical grid size stretching from 60 m near the ground to 300 m at 11 km.

The initial conditions are taken from a composite sounding representing Charlotte's environment at 2200 UTC. As confirmed from observations, TASS produces an intense, microburst-producing cell of small diameter and vertical depth that drifts toward the northwest (see Table 1).

**Table 1.** Comparison Between Observed and TASS Simulated Storm Characteristics

	OBSERVED*	TASS
Storm Top	7 - 9 km	8 km
Peak Radar Reflectivity	>50 dBZ	65 dBZ at 3 - 4 km AGL
Storm Translation	4.5 m/s from 150° (toward NW)	3.8 m/s from 145°
Radar Echo Structure at Mid-Levels	Elongated WNW-ESE	Elongated WNW-ESE
Diameter of Rain shaft	Estimated 1.5 to 5 km	~3.5 km
Temperature Drop	-6° C at NWS	-7° C
Max (1-km) N-S F-factor	~ 0.3 from FDR of FL 1016	0.3
Peak Low-Level Gust	17.3 m/s - LLWAS, 20-25 m/s estimated by civilians	27 m/s
Max N-S Velocity Differential ( $\Delta V$ )	35-40 m/s from FDR of FL-1016	44 m/s
*From the following sources as reported in Salottolo (1994) and Ritter (1994): aircraft weather radar and FDR data; pilot and eye-witness interviews; NWS surface obs; Columbia, SC, NEXRAD radar; and LLWAS.		

TASS results indicate that surface rainfall rates were increasing rapidly in the two minutes prior to the accident, reaching a peak of over 4 in/hr (Fig. 1). Also shown in Fig. 1 is the 1-km averaged F-factor,  $\langle F \rangle$ , a windshear hazard index that quantifies the impact of windshear on the aircraft energy state. The computation of  $\langle F \rangle$  from TASS data is as described in Proctor and Bowles (1992). The peak values of  $\langle F \rangle$  are

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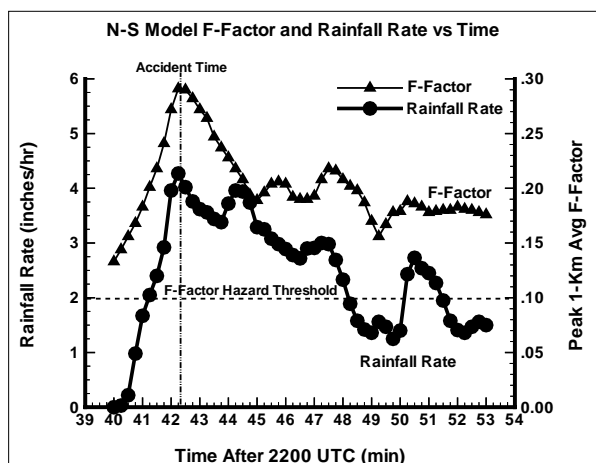


Figure 1. Peak 1-km average F-factor and surface rainfall rate vs time from TASS. Peak F-factor represents maximum value along any north-south segment below 1 km AGL.

well above 0.1, a value which the FAA has selected as a threshold for annunciating a warning from airborne windshear alerting systems.

Reconstruction of the flight path from the model data and matching of model coordinates to the actual, follows that in Proctor and Bowles (1992). The TASS wind field at accident time (Fig. 2) indicates that the microburst is centered just north of the runways and is resolved by only one of the LLWAS anemometers. This location would expose landing aircraft to windshear at a critical time. An aircraft following FL-1016 also encountered the microburst, but had aborted landing and applied a "go-around" procedure, although unable to gain

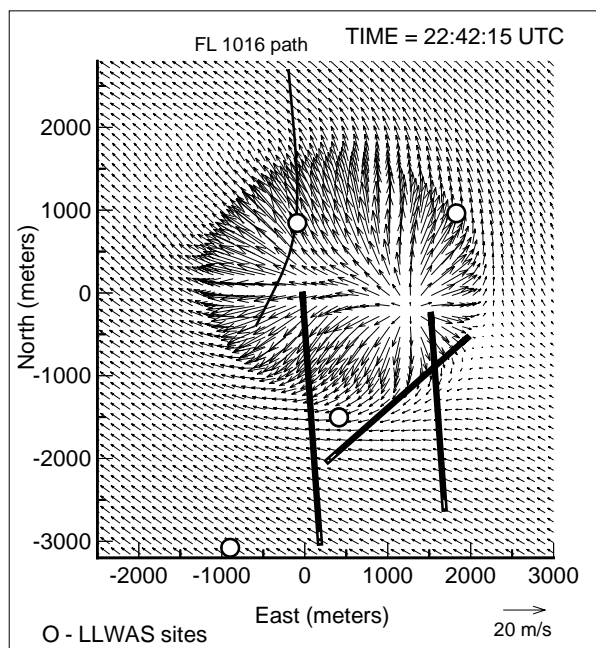


Figure 2. Horizontal wind vectors at 90m AGL near accident time as generated from TASS. Coordinates relative to threshold of 18R.

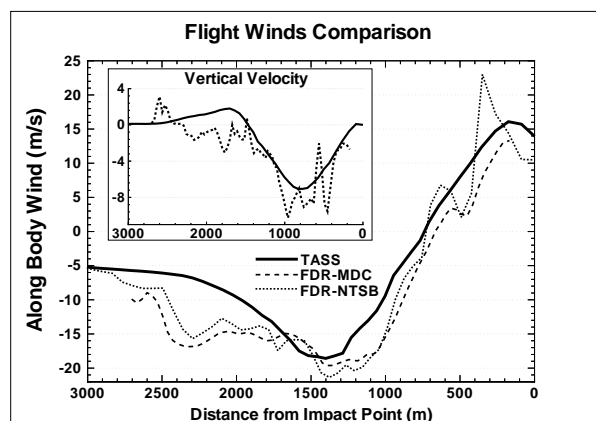


Figure 3. Comparison of reconstructed winds along flight path of FL 1016. FDR-MDC winds provided by McDonnell Douglas, FDR-NTSB provided by NTSB.

altitude. This aircraft was reported to have exited the microburst at a location 1/3 of the way down runway 18R, as is consistent with the flow field in Fig. 2.

A preliminary analysis of the winds from FL-1016's flight data recorder (FDR) was provided by both McDonnell Douglas (MDC) and NTSB. MDC's winds were derived from the integration of the accelerometer data and filtered with ATC radar data, while NTSB's winds were derived from positional data. The wind profiles from both sources and TASS are shown in Fig. 3. A comparison of  $\langle F \rangle$  that is computed from these wind profiles is shown in Fig. 4. The aircraft first encountered a weak performance-enhancing area of the microburst (indicated by negative values of  $\langle F \rangle$ ) followed by an unusually intense performance-decreasing area with a peak  $\langle F \rangle$  of about 0.3 (in large microburst samples values above 0.25 are atypical, e.g. Bowles and Hinton 1990).

### 3. RADAR SIMULATION

Detection of this event by on-board look-ahead windshear radar is investigated via radar simulation with the TASS data base. The simulated radar is based upon a NASA windshear radar designed, developed, and flight validated as part of the NASA/FAA windshear program (Harrah et al 1993). This

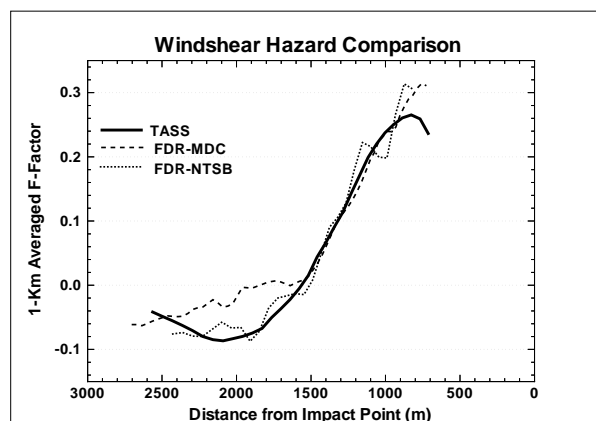


Figure 4. Same as Fig. 3, but for 1-km averaged F-factor.

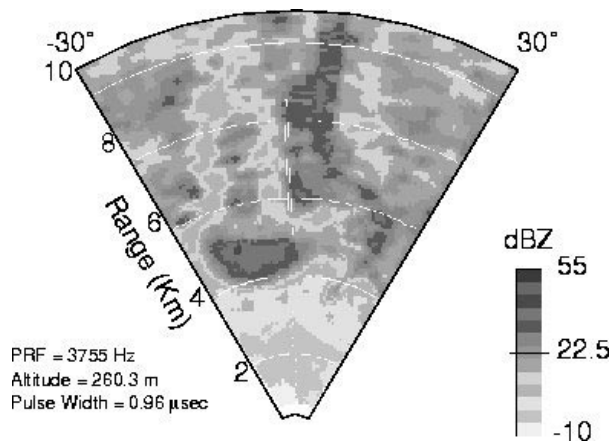


Figure 5. Simulated radar reflectivity with clutter as viewed by on-board windshear radar.

system is based upon current state-of-the-art, X-band, weather radar technology and employs NASA developed processing algorithms for: microburst detection, estimation of hazard severity, and alerting criteria (Bracalente et al 1990, 1994). The radar simulation program (Britt 1990; Britt et al 1994) was developed by RTI, under a NASA contract, for development and testing of windshear radar designs.

The simulation assumes a flight path on approach to 18R. It was run with Philadelphia ground clutter (Harrah et al 1992), an urban clutter field that poses a more difficult windshear detection scenario (Charlotte clutter was unavailable). The simulation showed that the radar reflectivity from the microburst rainshaft was not easily distinguishable from the ground clutter (Fig. 5). However, in spite of the ground clutter, the simulated radar was able to identify the microburst hazard and issue a warning some 60 s prior to accident time (Fig. 6). The area of strongest hazard is located left of the flight path in Fig. 6, but drifts into the flight path as the aircraft approaches the runway.

#### 4. CONCLUSIONS

Reconstruction of the event leads us to believe that FL-1016 encountered an intense, rapidly forming, microburst of relatively small scale. Results from the radar simulation indicate

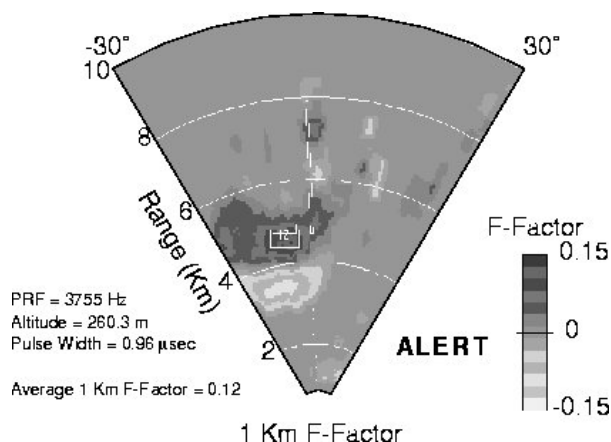


Figure 6. Same as Fig. 5, but for windshear hazard.

that an aircraft on approach could have received adequate warning if equipped with a windshear radar.

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